Ninth Quarterly Progress Report

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Feasibility of an Intra-Neural Auditory Prosthesis Stimulating Electrode Array

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1. Introduction

The objective of this research is to evaluate the feasibility of intra-neural stimulation as a means of implementation of an auditory prosthesis. We are stimulating the auditory nerve with penetrating multi-channel electrode arrays and monitoring the thresholds and tonotopic spread of activation in the central nucleus of the inferior colliculus (ICC) of cats.

2. Summary of activities for the quarter

In the present quarter, we conducted acute physiological experiments in four cats, we continued human temporal bone studies with otologic surgeons Alex Arts and Mark Wiet, and we continued discussions with members of the U-M College of Engineering regarding chronically implantable intra-neural arrays. The first peer-reviewed publication from this contract appeared in print: Middlebrooks, JC, and Snyder, RL: Auditory prosthesis with a penetrating nerve array, JARO 8:258-279, 2007. Invited presentations were given at the American Auditory Society meeting in Phoenix and at Biyomut 2007 (Biomedical Engineering Conference), Bogazici University, Istanbul, Turkey.

The principal accomplishments of this quarter were the following:

- *Continued temporal-bone dissections for evaluation of surgical approaches for placement of intra-neural stimulating arrays in humans.* We are continuing to work with two otologic surgeons at the University of Michigan, Alex Arts and Mark Wiet, to identify the optimal surgical approach for intra-neural array placement. Prompted by this work, Drs. Arts and Wiet are preparing for submission a paper on an infra-labyrinthine approach and soon will begin preparation of a paper on a trans-labyrinthine approach.
- *Lateral approach to the auditory nerve with preservation of hearing.* In three cats, we implanted intra-neural arrays while maintaining near-control thresholds for acoustic hearing at all but the highest tested frequencies; in the fourth animal, thresholds were elevated due to an experimental mishap. In animals in which acoustic hearing was preserved, we recorded sound-evoked spike activity from the implanted auditory-nerve electrode array. The quality of recording ranged from multi-unit activity to, in a few instances, well isolated single units. Final analysis is not complete, but we estimate that we now have sufficient data to write a manuscript documenting preservation of acoustic hearing during intra-neural array placement and recording of sound-evoked auditory nerve spike activity.
- *Transmission of temporal information from the electrically stimulated auditory nerve to the ICC.* We continued studies of transmission of temporal information begun in previous quarters. We are comparing phase locking of ICC units to various electrical stimuli of the auditory nerve. The stimulus waveforms include unmodulated pulse trains that vary in pulse rate and sinusoidally amplitude modulated (SAM) pulse trains that vary in modulation frequency and depth and in carrier pulse rate. Electrical stimulus configurations include intra-neural electrodes stimulating auditory nerve fibers from apical, middle, and basal turns, monopolar and bipolar stimulation through a conventional intra-scalar electrode array, and a ball electrode placed in the apical scala tympani. The results obtained in this quarter are consistent with our findings presented in Quarterly Progress Report 8. Generally, phase locking extends to the highest frequencies under conditions that lead to activation of low-characteristic-frequency (low-CF) pathways to the ICC. These conditions include intra-neural stimulation of apical fibers and intra-scalar stimulation with the apical ball electrode.

Transmission of temporal information from the intra-neural electrode array is superior to that obtained with intra-scalar stimulation only insofar as the intra-neural electrodes have better access to low-CF pathways. Considerable quantitative analysis remains to be completed, but we estimate that we now have sufficient data to write a manuscript documenting transmission of temporal information using various modes of cochlear electrical stimulation.

3. Plans for next quarter:

- Conduct and document dissections of human temporal bones to refine the trans-labyrinthine approaches. Prepare a manuscript.
- Compile results from tests of preservation of acoustic hearing. Prepare a manuscript.
- Complete quantitative analysis of transmission of temporal information.
- Conduct physiological experiments in 4 cats, testing a new ICC recording array intended for chronic use.